INTEGRATED PROCESS FOR COALBED BRINE
AND
METHANE DISPOSAL

By
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Abstract

This paper describes a technology and project to demonstrate and commercialize a brine disposal process for converting a brine stream from conventional and non-conventional gas production into clean water for agricultural use and dry solids that can be recycled for industrial consumption. The process also utilizes coalbed methane(CBM) released from coal mining or conventional natural gas wells for the combustion process . Utilizing CBM as the fuel source substantially reducing the potential for methane emissions to the atmosphere. This technology is ideally suited for the treatment and disposal of produced brines generated from the development of coal mines , coalbeds ,and conventional methane resources worldwide. Over the next 10 to 15 years, market potential for brine elimination equipment and services is estimated to be in the range of $1 billion.

Aquatech Services, Inc. (Aquatech) is an environmental technology development and service firm located in northern California which has developed proprietary processes for treating variable, complex, saline waste waters (produced brine) for environmental compliance and beneficial reuse.

Following initial testing in California and New Mexico, the basic process has been demonstrated in a 50 m3/ day pilot plant at the Morcinek Mine, a part of the Jastrzebska Coal Consortium in Upper Silesia, Poland. It is anticipated that with financial support from international lending institutions and continued support from the Government of Poland, several commercial installations will be built and operated.

Statement of the Problem

According to the American Gas Association, coalbed methane is recognized as a vast undeveloped energy resource. Potential world-wide reserves of coalbed methane have been estimated at 4,000 to 7,000 trillion cubic feet. Significantly, these resources are distributed across all continents. However, more than 90% of total reserves are located in 13 countries: the U.S., Canada, China, Poland, Russia, India, Kazakstan, Australia, South Africa, Zimbabwe, Botswana, Germany, and the United Kingdom. U.S. CBM reserves are estimated at 400 trillion cubic feet. In many countries, coalbed methane reserves dwarf remaining natural gas resources, and are a significant indigenous hydrocarbon resource.

Methane is present in virtually all coal bearing formations and has long been recognized as a serious hazard to mining operations. Safe practice requires that methane be removed from the coal matrix prior to commencing mining operations. Traditionally, this has been accomplished by drilling vertical extraction wells. Recovered methane has then been typically vented to atmosphere.

Green House Gas(GHG) emission reduction is an international goal established by the UN Convention on Climate Change in 1992. The Aquatech process provides a method of using coalbed methane rather than releasing it raw to the atmosphere. Mines that release coalbed methane as a byproduct will be restricted in the future unless the treatment and disposal of produced brines and methane are provided for in a legally accepted manner.

Historically, coalbed methane has only been marginally utilized as an energy resource. This is changing, and today coalbed methane is viewed as a potentially vast new energy resource.

The process offers an economically viable alternative to disposal by injection. The current regulatory framework in the U.S. effectively limits disposal options to deep well injection, or demineralization and beneficial reuse. A 1993 study conducted by the Gas Research Institute identified the cost of deep well injection as ranging as high as $0.75/barrel for on-site and $3.50 for off-site wells. The Aquatech process offers comparable disposal economics of between $0.75 and $1.25/barrel, depending on treatment volumes and site conditions. While this process technology will not immediately displace deep well injection, it provides an attractive alternative where site conditions or permit constraints prohibit deep well injection or where a waste to resource conversion is attractive.

Industry analysts forecast that over the next five years, additional volumes of produced water from gas production in the U.S. will conservatively total some 320,000 m3/day (84.5M gal/day). Based on the assumption that only 30 percent of this total will require disposal by treatment and beneficial reuse, this represents a potential market for $254 million in technology and equipment sales. In addition, Eastern Europe represents major market potential for produced water treatment equipment of more than $400 million based on U.S. Government studies.

Gas, oil and coal mining operations generate large volumes of produced water. Produced water or brine, is often a highly contaminated effluent which is co-produced along with the oil and gas. Once the energy fraction is separated and recovered, residual contaminated brines must be disposed of in compliance with federal and local statutes. Energy producers are continually seeking to improve economics by decreasing production costs and by lowering field expenses. In certain circumstances , the Aquatech process can be an attractive alternative to conventional techniques for produced water disposal. Industry is under increasing pressure to find alternative, cost effective methods for the treatment and disposal of these effluents.

Brine disposal problems are most acute in the development of coalbed methane. On the average, coalbed gas wells produce 13.5 times the volume of produced water as do natural gas wells In 1990, Coalbed methane accounted for less than 2% of total U.S. gas production but represented 13% of total produced water. Before these vast methane resources can be commercially developed, environmentally acceptable methods for brine disposal will need to be adopted by the industry.

Using gas directly from producing wells to fuel the combined process described can extend the field productivity. This results in substantially lower production costs, and improved well operating profiles, and legal compliance for disposal of the brine produced at these sites. Other commercial applications would include power plants and the reduction of hydrocarbon pollution in other effluent streams.

Commercial opportunities are being developed in eastern Europe, the focus of the Company's initial marketing efforts. The Polish project described in this paper has the endorsement and support of the Jastrzebska Coal Consortium in Upper Silesia, and the Polish Ministry of Environmental Protection and Natural Resources and the international ECOFUND. It is being jointly carried out by Aquatech and Exbud-Metan, its Polish partner, under a technology demonstration and commercialization agreement between the parties.

Further opportunities have been identified in the Czech, Slovakian, Ukrainian Republics , China, and Russia. These markets will be developed concurrently with the Jastrebska Consortium projects. The Company intends to pursue U.S. market development along with the development of foreign commercial plants.

An Economic Solution

Disposal of produced brines into river systems in Poland and throughout eastern Europe have resulted in devastating ecological damage. Produced brines generated from the Jastrzebska Mine Consortium in Poland alone, represents a discharge of some 350 tons per day of salt directly to surface waters. The Polish Government has recently demonstrated its commitment to cleaning up these brine discharges by constructing a large pilot brine elimination system at a major mining operation. The international community and the mining industry provided both financial and technical support to remediate these discharges. However these systems were expensive, with treatment costs in excess of $5.00 per barrel.

Aquatech is focusing initially on the commercial development of the eastern European market where large-scale remediation projects are required. The Company is currently conducting a customer and DOE/EPA funded demonstration of the process at the Morcinek Mine near the city of Katowice in Upper Silesia, Poland. The mine authorities have stated that they intend to proceed with construction of a 2,500 m3/day brine elimination system once field trials are successfully concluded. This client controls seven separate mining operations and Aquatech is presently engaged in discussions with the consortium to prioritize its plans for construction of brine elimination systems at each of these mining operations. The initial target is a 2,500 m3/day (660,500 gal/day) system is valued at $7.5 million. The initial orders in Poland are expected to be obtained in 1997.

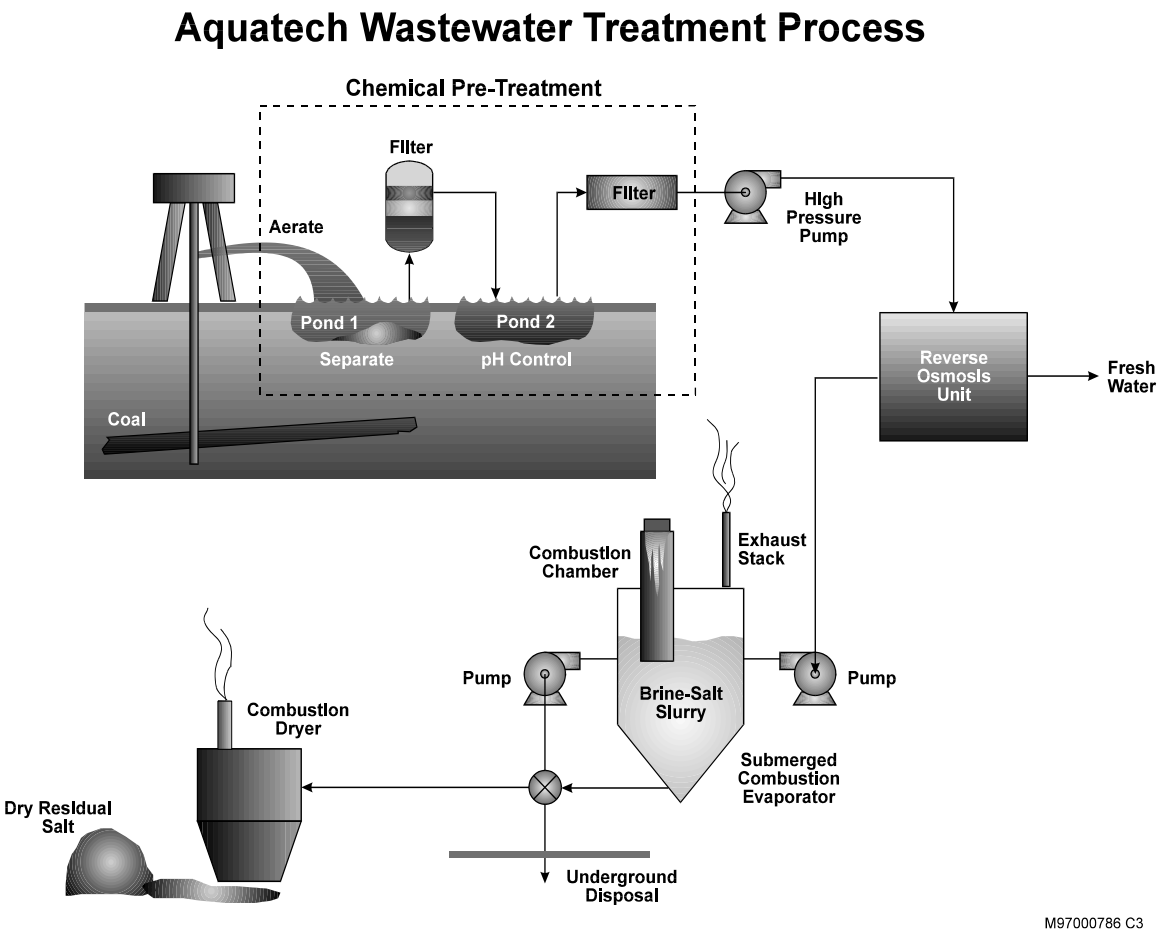
Process Description

The Aquatech system being demonstrated includes pretreatment regimes, membrane desalting (reverse osmosis), and submerged combustion concentration combined into a

highly effective brine disposal process. The process results in the reclamation of a portion of the stream (projected at 60% or greater) as high quality water for beneficial reuse for agriculture and industry. The remainder of the stream volume is reduced by thermal evaporation utilizing coalbed methane to fuel a submerged combustion brine concentrator rather than releasing the methane to the atmosphere directly. The process can achieve zero discharge operation in many applications.

Aquatech's process utilizes commercially available components in process steps configured in a proprietary manner. The process includes a pre-treatment step, followed by reverse osmosis (RO) seawater desalting. The RO permeate is of high quality and suitable for reuse as irrigation or industrial process water. The RO concentrate volume is further reduced using Aquatech's submerged combustion evaporator. If economic, the final evaporator concentrate can be converted into dry solids by means of a combustion drying step.

A simplified process schematic is provided in Figure 1.



Coalbed brines are typically complex waste streams with salinity concentrations which generally match or exceed that of seawater. Produced brines typically contain high concentrations of sparingly soluble salts, organics, and biological activity that are problematical to successful desalting using reverse osmosis separation. Aquatech's intimate knowledge and experience with these brines has enabled it to develop predictable pretreatment regimes which are key to the successful operation of the RO stage.

Following pretreatment, the brine is desalted and concentrated by means of a high pressure, seawater RO system. In the reverse osmosis stage, pretreated brine enters the membrane banks under pressure. RO membranes allow pure water to permeate the membrane barrier layer while rejecting the dissolved salts. As fresh water is produced, the rejected salts are concentrated in the reject stream. The permeate is high quality and suitable for surface discharge, groundwater recharge, or beneficial reuse. Aquatech has pioneered techniques to enable high recovery reverse osmosis system operation. These techniques substantially improve the overall economics of the brine elimination process and provide a cost effective solution.

The RO reject or concentrate stream then enters the submerged combustion evaporator. During submerged combustion evaporation, a mixture of coalbed methane and air is ignited. Combustion occurs in a burner that is submerged into a liquid bath. Combustion takes place above the brine level while the combustion gases are vented through the brine. Heat transfer from the combustion gases to the brine is extremely efficient because the heat from these gases passes directly through the brine in intimate contact. The produced water vapor, together with the combustion products, vent into the atmosphere. Mist eliminators are installed in the exhaust stack to insure that no brine droplets are emitted from the stack.

Brine (concentrate) from the reverse osmosis unit is continuously fed to the evaporator. Concentrated brine is bled from the evaporator at a controlled rate so that a steady state brine concentration is established in the evaporator. The water evaporated from the brine produces a steady state salt concentration in the evaporator. The control system balances the rates of brine evaporation and brine discharge, to produce steady state operation. At this stage of the process, the original volume has been reduced by more than 90 percent.

The brine mixture from the submerged combustion evaporator, once elevated to 25% solids, is delivered to a dryer that completely removes the residual water. The resulting product is composed of solid salt particles which can either be recycled for commercial use or safely disposed of in a sanitary landfill. At a minimum, the process offers total brine volume reductions of greater than 95%.

In a typical domestic brine stream of 1,000 m3/day (6,290 bpd) having a total dissolved salt concentration (TDS) of 7,000 ppm, it will be separated into a permeate stream of 750 m3/day (4,718 bpd) with a TDS of 400 ppm and a concentrated brine stream of 250 m3/day (1,573 bpd) with a TDS of 26,800 ppm. The submerged combustion evaporator will concentrate this latter stream to a concentration of 268,000 ppm and

reduce the volume to 25 m3/day (158 bpd). A pulse combustion dryer can dry the concentrated brine mixture to a low moisture salt.

Process Benefits

This proprietary process offers the following benefits for the treatment and disposal of produced water effluents from natural gas production and coal mine operations worldwide:

- elimination of high salt discharges, thus achieving regulatory compliance and
- elimination of liabilities resulting from ground or surface water contamination;
- elimination of methane discharges now being vented to the atmosphere;
- reclamation and beneficial reuse of a portion of the stream as high quality water for use in crop irrigation and industry;
- ability to achieve zero discharge operation by recycling the stream to obtain industrial grade salts;
- capital and operating economics competitive with alternate disposal methods;
- full regulatory compliance.

Conclusions

A combination of chemical pre-treatment, reverse osmosis separation, submerged combustion evaporation, and pulse combustion drying provides a system for cost-effective recycling and disposal of brine associated with methane production. The pre-treatment process can be optimized with chemical modeling codes and the use of customized pretreatment schemes and reverse osmosis membranes. Because the composition of brines from coalbeds and methane production are very complex, successful pre-treatment for reverse osmosis separation requires detailed modeling of the chemical and thermodynamic changes of the brine as it flows through the process.

The demonstration of the process is to be completed by June 1997 and the initial commercial applications are being developed. The success of these commercial ventures however will not depend only on a successful demonstration but also on markets driven by the enforcement of environmental regulations in countries where coalbed methane is currently released to the atmosphere and brines are released untreated into the natural water systems. With the enforcement of regulations and the establishment of environmental credits for CO_2 sequestration, will come additional commercial opportunities and markets which will lead to successful international and domestic opportunities for the process.

Acknowledgments

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